Developing Effective Embedded Training

Janis A. Cannon-Bowers, Ph.D.
Institute for Simulation and Training
University of Central Florida
3100 Technology Parkway
Orlando, FL 32801

ABSTRACT

Embedded training systems have several unique requirements as compared to more traditional training systems. For the most part, these requirements stem from the fact that traditional instructors and other technical support personnel are not typically available in the operational environment. Hence, embedded training must be essentially stand-alone systems. This requirement means that embedded training systems must be highly automated and intelligent.

As a starting point, it must be noted that developing effective embedded training systems should hinge on sound research into how people learn. In addition, modern technology offers a variety of capabilities that were not available even 5 years ago. Taken together, principles of learning supported by technology can yield effective embedded training systems. The sections that follow lay out the components of an effective embedded training system. It begins with tenets from scenario-based training and then adds components of intelligent tutoring.

1.0 SCIENCE BEHIND SCENARIO-BASED TRAINING

The challenge of building adaptive expertise is a major thrust in most modern Military training. Over the past thirty years, the development of expertise has been the focus of much study. Based on this body of work, theoretical justification has been amassed for the proposition that providing trainees with realistic scenarios can be an effective means to accelerate the development of expertise. Such justification can be found in several lines of research into how people learn. In this regard, Glaser (1989) argued that "beginners' knowledge is spotty, consisting of isolated definitions and superficial understandings of central terms and concepts" (p. 272). Over time, these items of information become more structured and are integrated with past organizations of knowledge, eventually being stored as condition-action rules in memory. Thus, through acquisition of domain knowledge, experts build up a repertoire of instances—or patterns--indexing them in such a way that they are rapidly accessible when triggered by environmental cues (Chi, Glaser, & Farr, 1988, p. xvii; Gobet & Simon, 1996; Logan, 1988). Experts also appear to "chunk" information into related packets, and recognize meaningful patterns in the problem space, a finding that has been replicated across domains (Egan & Schwartz, 1979; DeGroot, 1965).

Based on this and other work, principles for the design of effective learning systems are numerous. First, the notion that learning should occur in a *meaningful or relevant context* is supported by these theoretical positions. Second, expert knowledge is *conditionalized* (i.e., specific to a context) and develops over time through repeated exposure to instances of the task (which is another way of saying experience). New learning, in turn, must be integrated into this existing world knowledge.

Research over the past 20 years has produced results that can enable the development of learning environments that are consistent with principles noted above. For example, simulations that afford trainees opportunities for practice and experimentation have proven very effective in a variety of contexts (Stout et

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE
OCT 2009

2. REPORT TYPE
N/A

3. DATES COVERED
-

4. TITLE AND SUBTITLE
Developing Effective Embedded Training

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Institute for Simulation and Training University of Central Florida 3100 Technology Parkway Orlando, FL 3280

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADA562526. RTO-MP-HFM-169 Human Dimensions in Embedded Virtual Simulation (Les dimensions humaines dans la simulation virtuelle integree)., The original document contains color images.

14. ABSTRACT
Embedded training systems have several unique requirements as compared to more traditional training systems. For the most part, these requirements stem from the fact that traditional instructors and other technical support personnel are not typically available in the operational environment. Hence, embedded training must be essentially stand-alone systems. This requirement means that embedded training systems must be highly automated and intelligent. As a starting point, it must be noted that developing effective embedded training systems should hinge on sound research into how people learn. In addition, modern technology offers a variety of capabilities that were not available even 5 years ago. Taken together, principles of learning supported by technology can yield effective embedded training systems. The sections that follow lay out the components of an effective embedded training system. It begins with tenets from scenario-based training and then adds components of intelligent tutoring.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**6**	

al., 2008). However, the effectiveness of any training system—simulation-based or otherwise—depends on how well the system is designed and whether it embodies sound instructional features (Salas & Cannon-Bowers, 2000). In the case of simulation, much of the instructional power is actually attributable to the nature of the *scenario* that is expressed in the simulated environment. Hence it is imperative to understand how to design and implement effective scenarios as a means to optimize scenario-based training.

2.0 A FRAMEWORK FOR DESIGNING EFFECTIVE SCENARIO-BASED TRAINING (SBT)

Cannon-Bowers et al. (1998) proposed an overarching framework to describe the SBT process based on extensive experience in training Navy combat teams. This process has been modified over the years; the updated version can be seen in Figure 1.

[Insert Figure 1 about here]

The SBT process shown in Figure 1 provides an organizing framework for couching a discussion of SBT. The following sections provide more detail about the SBT process and describe how each step in the process contributes a crucial component that optimizes the overall system performance and effectiveness.

2.1 Task Analysis and Learning Objectives

It has long been acknowledged that a detailed task analysis is a first essential step in developing any training system. It stands to reason that the targeted task and domain must be well understood before training can be developed, and job/task analysis methods to accomplish this have been existence for many years (Annett & Stanton, 2006). However, traditional task/domain analysis processes are deficient for several reasons.

First, more attention is being paid to higher order skills, especially critical thinking, decision-making and problem solving. This has resulted in efforts to better understand how experts perform in realistic environments, including specification of the *tacit* or *implicit* knowledge that is involved—such knowledge is crucial to task performance, but not well articulated by the experts themselves (Cianciolo, Matthew, Sternberg, & Wagner, 2006). Hence, cognitive task analysis—which represent less direct methods of eliciting knowledge from experts--have been developed in recent years as a means to understand more completely how an expert would perform the task.

Next, task analysis data must cast into a set of observable, measurable learning objectives for an exercise or training event. This step may seem obvious, but is often overlooked; it is crucial for several reasons. First, it helps to organize the scenario and ensure that the most important knowledge and skills are addressed. Second, it helps to ensure that the exercise is targeted appropriately for the learners—so that it is neither too easy (and hence not challenging), nor too overwhelming so that trainees cannot gain maximum benefit. In addition, formally stating learning objectives at the onset of an exercise is important so that it is clear what is to be covered and that trainees are practicing a manageable number of skills. Finally, the learning objectives for an exercise or event should lead directly to a set of measurable outcomes (more will be said about performance measurement in a later section).

3.0 SCENARIO: EVENTS AND STORY

Once the learning objectives have been established, they can then be used as input to develop scenarios, which form the basis of a training exercise. With respect to developing effective scenarios, past researchers have conceptualized this process in terms of *embedding events* into scenarios that represent the

learning objectives. An event, in this context, is any stimulus condition that is purposely scripted into a scenario in order to elicit a particular response. Scenario events have also been conceptualized as *triggers*—specific scenario conditions that will allow the trainee to practice the targeted learning objectives (Fowlkes et al., 1998) as a means to demonstrate proficiency and/or as a basis for feedback. Hence, the scenario events are the basis of a trainee's practice opportunities.

The scenario in SBT also serves another purpose; that is, to provide a context or narrative that ties events together. In this sense, the scenario or *story* also serves a motivational purpose because it engages the trainee in a realistic context. Researchers have recently begun to theorize that narrative elements may actually enhance learning by helping guide trainees through the system (Ironside, 2006). Further, recent research into concepts such as *immersion* and *presence* seems to indicate that learning can be enhanced when trainees are psychologically engaged in the scenario (Whitmer & Singer,). Stories and story-based learning also help to ensure that the experiences trainees gain in training (as opposed to the real world) are authentic—that is, they are rich, faithful representations of the world that will enable the trainee to transfer his/her virtual experience into the real environment. This includes the affective or emotional aspects as well as more cognitive and behavioral.

3.1 Performance Measurement/Metrics/Diagnosis

Once scenario events are scripted and instructional strategies selected, the next step in the SBT development process is to specify the performance measures that will be implemented to assess trainee actions and behaviors. In general, performance measurement is challenging in high performance environments because it is difficult to assess complex, and often times unobservable, performance. For example, in many cases, the situation is unfolding rapidly and there are many things going on at once (this is particularly true in team situations). Therefore, simply sorting tracking and sorting through trainees' performance is complicated.

It is also often difficult to evaluate performance since it is impossible to track a trainee's thought process directly. Hence, instructors may not be able to comment on the process that the trainee used to arrive at a conclusion or action. Further, establishing standards of performance—this is, a set of criteria that describe desired performance—is not feasible in uncertain, ambiguous decision making situations where there are many possible ways to solve a problem.

Perhaps the most important function of performance measurement is the ability to diagnose the causes of observed performance. That is, it is not sufficient to say that a trainee performed poorly--in order to intervene so that performance can improve, it is essential to understand *why* the behavior was demonstrated. For example, if the student's performance can be attributed to a lack fundamental knowledge, this would suggest one remediation strategy, while a deficiency in skills (e.g., communication) would suggest an entirely different one.

3.2 Instructional Strategies

SBT environments provide a context in which learning can occur, but they are not training systems in and of themselves, without additional elements displayed in Figure 1. The establishment of instructional strategies that optimize learning is of primary importance here; there are several possible approaches to embedding instruction in SBT. For example, instructional decisions can be made regarding the difficulty of tasks presented to trainees, the form and timing of feedback (more will be said about this in a later section), the nature of hints and cues provided to trainees, the spacing of practice opportunities, and the like. Consideration of the nature of the learning objectives, as well as the trainees' level of mastery, are critically important in this regard.

3.3 Feedback & Remediation

As noted, feedback is an essential element in SBT, as it is in all forms of training. Feedback provides trainees with a detailed understanding of their performance and what needs to be corrected in order to enhance subsequent performance. Much has been written about feedback in training, including issues such as: when and how often to give feedback, the format of feedback (e.g., directive or reflective), the specificity of feedback, and who provides feedback (instructors or trainees themselves. The literature provides much useful guidance on how best to implement feedback mechanisms in training. In SBT, feedback is a primary mechanism for imparting targeted objectives; hence it must be carefully developed and implemented.

3.4 Learning Management

A final step in the SBT process is to record trainee performance, and use that information to guide future training exercises. In operational environments this is often accomplished informally, rendering subsequent training sessions less effective than they could be. The requirement is to accurately identify and record the trainees' level of mastery so that future training events can be tailored to their needs. Otherwise, the possibility of repeating practice on learning objectives that have already been mastered is high. It is necessary in this regard that performance outcomes from SBT exercises be carefully recorded so that they can inform subsequent training.

3.5 Intelligent Tutoring

Traditional intelligent tutoring systems seek to automatically track, interpret and act upon real time trainee performance data. The history of intelligent tutoring spans the last 20 years, and for the most part, successful tutors have been implemented for static tasks (such as math, programming). More complex environments have typically exceeded the ability of systems to track and interpret data. Further, models of complex performance have typically not been available. Modern technology is providing new capabilities that may be able to address these deficiencies.

3.5.1 Components of Intelligent Tutoring

Traditional intelligent tutoring systems have several key components. These include:

- Expert model—detailed model of expert performance used as a means to compare observed student performance.
- Student model—executable model of student performance that is built up over time based on observed (on-going) student performance.
- Instructional model—model that guides the specification of what should be done (feedback/remediation) in response to various student performances
- Tracking mechanisms—instrumentation that allows collection of a variety of performance data including, keystrokes, eye gaze, head movements, body movements, verbal responses, and/or instructor input.
- Simulation—typically, intelligent tutoring for dynamic tasks are based on some type of simulation.

These components are compatible with the scenario-based training model offered above. When combined, these capabilities have the potential to provide Intelligent Embedded Training systems that can be implemented in operational environments—without much support from instructors or other technicians.

A vision of intelligent embedded training includes automated scenario generation capabilities that allow instructors to easily develop new scenarios that correspond to changing mission requirements. Importantly, this process would also result in specification of performance measures and diagnostic routines, most likely developed through an interactive authoring dialog with the instructor. Once scripted, a new scenario would be easily implemented in the embedded training system so that trainees could automatically receive feedback about their performance.

4.0 THE WAY AHEAD

Early attempts to develop Intelligent Embedded Training met with only limited success, and few, if any such systems are in use. However, emerging technologies offer promise in this regard, and computing power has grown to the point where even data intensive systems are feasible.

REFERENCES

[1] Annett, J., & Stanton, N. (2006). Task Analysis. International review of industrial and organizational psychology (Vol 21) (pp. 45-78). Hoboken, NJ, US: Wiley Publishing.

[2] Cannon-Bowers, J., Burns, J., Salas, E., & Pruitt, J. (1998). Advanced technology in scenario-based training. Making decisions under stress: Implications for individual and team training (pp. 365-374). Washington, DC, US: American Psychological Association.

[3] Chi, M. T. H., Glaser, R., & Farr, M. J. (Eds.). (1988). The nature of expertise. Hillsdale, NJ: Lawrence Erlbaum Associates.

[4] Cianciolo, A., Matthew, C., Sternberg, R., & Wagner, R. (2006). Tacit Knowledge, Practical Intelligence, and Expertise. The Cambridge handbook of expertise and expert performance (pp. 613-632). New York, NY, US: Cambridge University Press.

[5] DeGroot, A. (1965). Thought and choice in chess. The Hague: Mouton.

[6] Egan, D. E. & Schwartz, B. J. (1979). Chunking in recall of symbolic drawings. Memory & Cognition, 7, 149-158.

[7] Fowlkes, J., Dwyer, D., Oser, R., & Salas, E. (1998). Event-based approach to training (EBAT). International Journal of Aviation Psychology, 8(3), 209-221.

[8] Glaser, R. (1989). Expertise in learning: How do we think about instructional processes now that we have discovered knowledge structure? In D. Klahr & D. Kotosfky (Eds.), Complex information processing: The impact of Herbert A. Simon (pp. 269-282). Hillsdale, NJ: Lawrence Erlbaum Associates.

[9] Gobet, F. & Simon, H. A. (1996). Recall of random and distorted positions: Implications for the theory of expertise. Memory and Cognition, 24, 493-503.

[10] Ironside, P. (2006, August). Using narrative pedagogy: Learning and practising interpretive thinking. Journal of Advanced Nursing, 55(4), 478-486.

[11] Lesgold, A. (1988). Toward a theory of curriculum for use in designing intelligent instructional systems. In H. Mandl & A. Lesgold (Eds.), Learning issues for intelligent tutoring systems (pp. 114-137). New York, NY: Springer-Verlag.

[12] Logan, G. D. (1988). Toward an instance theory of automatization. Psychological Review, 95, 492-527.

[13] Salas, E., & Cannon-Bowers, J.A. (2000). Design training systems systematically. In E.A. Locke (Ed). Principles of Organizational Behavior: A handbook, (pp.43-59). London: Blackwell.

[14] Stout, R.J., Bowers C.A., &Nicholson, D.M. (1998). Guidelines for using simulations to train higher level cognitive and teamwork skills. In D. Schmarrow, J. Cohn & D. M. Nicholson (Eds.), Handbook of virtual environments for training and education: Developments for the Military and beyond, Portsmouth, NH: Greenwood Publishing Group.

[15] Witmer, B.G. & Singer, M.J. Measuring Presence in Virtual Environments: A Presence Questionnaire. Presence, 7(3), 225-240.